

## Durham Research Online

---

### Deposited in DRO:

14 October 2008

### Version of attached file:

Published Version

### Peer-review status of attached file:

Peer-reviewed

### Citation for published item:

Bridgland, D. R. and Philip, G. and Westaway, R. and White, M. (2003) 'A long quaternary terrace sequence in the Orontes River Valley, Syria : a record of uplift and of human occupation.', *Current science.*, 84 (8). pp. 1080-1089.

### Further information on publisher's website:

<http://www.iisc.ernet.in/currsci/apr252003/contents.htm>

### Publisher's copyright statement:

### Additional information:

---

### Use policy

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a [link](#) is made to the metadata record in DRO
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Please consult the [full DRO policy](#) for further details.

# A long Quaternary terrace sequence in the Orontes River valley, Syria: A record of uplift and of human occupation

David R. Bridgland<sup>\*,†</sup>, Graham Philip<sup>\*\*</sup>, Rob Westaway<sup>§</sup> and Mark White<sup>\*\*</sup>

<sup>\*</sup>Department of Geography, University of Durham, South Road, Durham DH1 3LE, UK

<sup>\*\*</sup>Department of Archaeology, University of Durham, South Road, Durham DH1 3LE, UK

<sup>§</sup>16 Neville Square, Durham DH1 3PY, UK

**Mapping in the Homs region of Syria has revealed a hitherto unrecognized staircase of at least 12 gravel terraces of the upper Orontes River. The terrace gravels overlie Pliocene lacustrine marl and have been calcareously cemented into conglomerates, sometimes interbedded with cemented fine-grained alluvium. A tentative dating scheme, based on modelling the regional-scale surface uplift that has driven fluvial incision of ~400 m since the latest Miocene, and incorporating correlation with the dated terraces in the valley of the middle Orontes using height above the river, envisages terrace formation spanning at least the last 1.2 Ma.**

THE Orontes (al-Asi) is the principal river draining from western Arabia to the Levant coastline of the Mediterranean Sea. From its source in the Baq'a (Bekaa) Valley of Lebanon, on the flank of the Lebanon mountain range, it flows northwards across western Syria through the cities of Homs and Hama, reaching the sea near Antakya in southern Turkey (Figure 1). In northern Syria, the lower Orontes forms the axial drainage along the Ghab (Gharb) basin, which is a linear valley formed along the Dead Sea Fault Zone (Figure 1), the boundary between the African plate (to the west) and the Arabian plate (to the east) along which left-lateral relative plate motion is accommodated<sup>1</sup>.

Downstream of Antakya, the lowermost Orontes has incised a ~300 m deep gorge through the Amanus (Amanos) Mountains (Figure 1). A river terrace sequence has been recognized here<sup>2</sup>, but its study and correlation with the terraces further upstream in Syria are beyond the scope of this paper. Upstream of the Ghab basin, the Middle Orontes has incised similar amounts into the surrounding land surface<sup>3</sup>. The youngest phase of this incision has involved eroding a ~100 m deep 'inner gorge' that has substantial, albeit localized, river terrace deposits preserved along its flanks<sup>3-9</sup>. These have been a prolific source of Lower Palaeolithic artefacts<sup>10-12</sup> and, less commonly, biostratigraphical data indicating Middle

Pleistocene ages<sup>13-15</sup>. In the most recent summaries of this evidence<sup>3,9</sup>, a total of six distinct terraces has been recognized along this reach.

Above Homs, the upper Orontes flows through an open, low relief landscape, where its Quaternary record has not previously been studied in detail (Figure 1). In this, the present study area, the eastern valley side of the Orontes slopes gently from >650 m a.s.l. to river level at 480–510 m, over a distance of ~15 km. Although unspectacular, this landscape will be shown here to be the product of progressive valley incision during the Pleistocene.

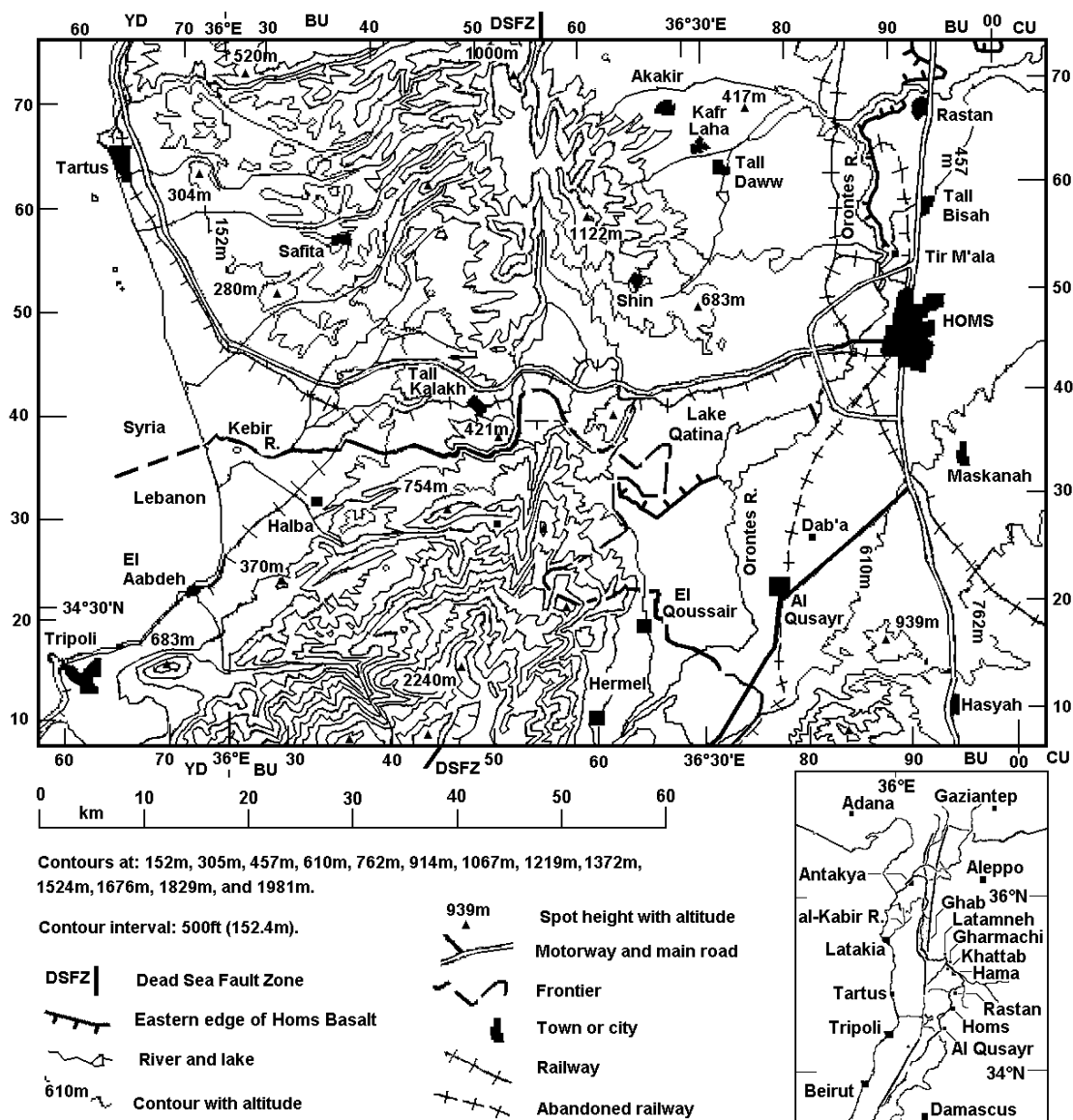
The upland topography between Homs and the Dead Sea Fault Zone, at altitudes of up to ~1100 m (Figure 1), is formed largely on the Homs Basalt (Figure 1), which was erupted between 5 and 7 Ma (latest Miocene to earliest Pliocene<sup>16,17</sup>). To the east, the remainder of the field area is floored by Neogene lacustrine marl of presumed 'Pontian' (i.e. latest Miocene) age<sup>18</sup>. Borehole evidence<sup>19</sup> reveals that the basalt continues below the surface beneath and east of Homs, where it is both underlain and overlain by lacustrine marls, those above the basalt presumed to be of Early Pliocene age.

## Mapping of Orontes terrace deposits

Within the subdued landscape of the Pliocene lacustrine marl outcrops are localized conspicuous blocks of calcareously-cemented chert/flint conglomerate. Such blocks commonly line roadsides, having been hauled there from fields, or occur as tilted slabs that may be roughly *in situ* but have been disturbed by ploughing or other activity. In the roadside piles they join blocks of the Pliocene marl or marly limestone, sometimes cemented into breccia, that have also been cleared from farmed areas. Occasional *in situ* conglomerates are seen in outcrop, often in patches amongst farmland where they have proved too difficult to remove, perhaps because of excessive thickness, or in the sides or beds of tracks. Rarely they are seen in quarry sections or cuttings.

These conglomerates were noted by Van Liere<sup>5</sup>, who interpreted them as slope deposits of 'Villafranchian'

<sup>†</sup>For correspondence. (e-mail: d.r.bridgland@durham.ac.uk)



**Figure 1.** Topographic map showing the study area in relation to the Dead Sea Fault Zone. Topographic information is from US Defense Mapping Agency Tactical Pilotage Chart G-4D at 1:500,000 scale. The eastern edge of the Homs Basalt is shown<sup>19</sup>, except where it coincides with the course of the River Orontes or is submerged beneath Lake Qatina. *Inset*, regional map, showing full drainage of the Orontes River in relation to international frontiers, the Dead Sea Fault Zone and location of the Homs Survey area.

(? Latest Pliocene) or Early Pleistocene age and described one site, located 'east of Qatina' (the name of the lake SW of Homs, Figure 1), where Acheulean hand-axes were found. Contrary to Van Liere's interpretation, the rare exposures in quarry sections and cuttings show that these cemented gravels occupy channels cut into the bedrock and that they are interbedded with finer-grained presumably alluvial sediments (Figure 2), suggesting that they are fluvial deposits. They display fluvial bedding structures, including stratification of different clast sizes and the typical subhorizontal disposition of clasts that typifies river gravels. Furthermore, their distribution in the landscape (Figure 3) suggests that they are terrace

deposits of the Orontes. This can be confirmed by a close approach to the river, where what is probably the most extensively-preserved conglomerate can be seen to form a low-level right-bank terrace, here named the al-Hauz Terrace, which can be traced for several kilometres distance upstream of Lake Qatina (Figure 4). At several places (Table 1), this terrace conglomerate is well exposed and displays characteristic fluvial bedding structures. At the type locality (2, Table 1), the conglomerate can be seen to extend right down to river level, suggesting that it is a thick aggradational gravel into which the modern river floodplain is incised, thus forming the lowest terrace of the Orontes (Figures 4 and 5).



**Figure 2.** Section through calcreted gravel and marly alluvial deposits in the Arjun quarry (Table 1, Locality 4).

These newly recognized terraces of the upper Orontes have been mapped in the area to the south and east of Lake Qatina, on the right bank of the river (Figure 1). This field area, part of an archaeological survey based on Homs, is effectively delimited to the south and west by proximity to the Lebanon border, to the north by the urban area of Homs and to the east, ~15 km from the Orontes floodplain, by the northward continuation of the Anti-Lebanon mountain range, which rises to ~1500 m (Figure 1). Unconsolidated gravels and finer-grained alluvial deposits have been recorded from construction sites in Homs, where it is reported that they overlie basalt boulders. Selected sites downstream from Homs, also within the archaeological survey area, have been included as they were found to have important exposures of terrace deposits (Table 1). It is intended that future

research will enlarge the mapped area in a downstream direction, so as to fully incorporate these localities. However, since the valley downstream from Homs becomes rapidly narrower and more incised, it is unlikely that there will be full preservation of the terrace staircase in that area.

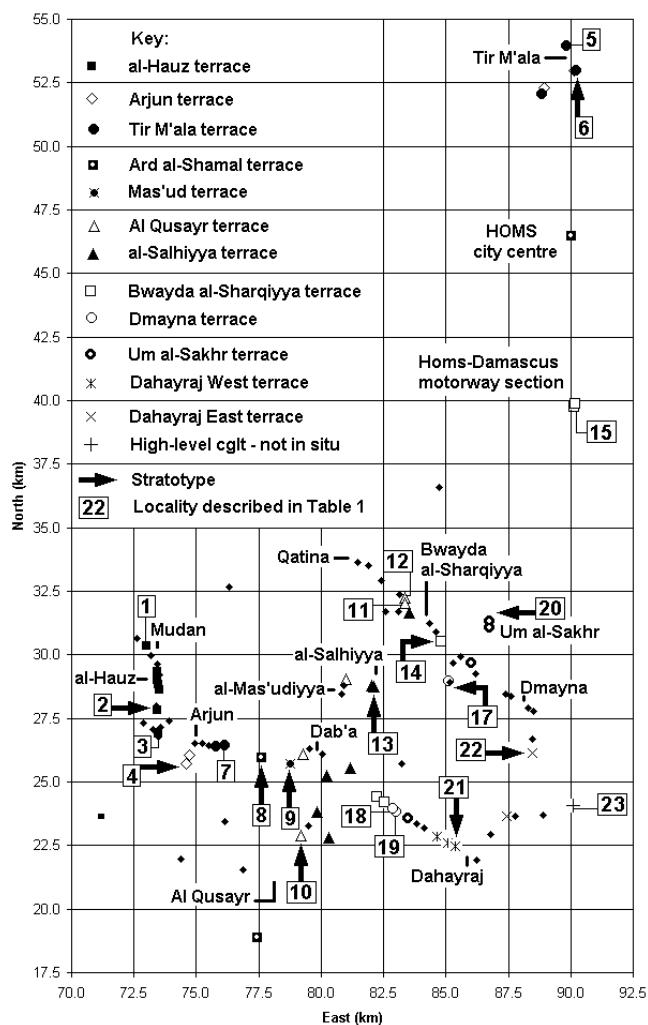
The terrace mapping undertaken to the south-west of Homs has involved the recording of outcrops of *in situ* flinty conglomerates and of bedrock marl, the latter important in delimiting 'bluff' areas in between terrace outcrops. In an area of subdued topography such as this, geological mapping was thought likely to prove superior to attempting mapping of geomorphological features, although it was possible to relate the disposition of conglomerate and bedrock outcrops to terrace 'treads' and bluff slopes in some instances. The heights above river

# SPECIAL SECTION: LATE CENOZOIC FLUVIAL DEPOSITS

**Table 1.** Upper Orontes terrace stratotypes and other key localities, numbered sequentially (see Figure 3 for locations)

Terrace	Height	Locality (type locality)	UTM coordinates; height a.s.l.	Description	Correlation [suggested OIS stage and age]
al-Hauz	5 m	1. Mudan 2. Right bank of the Orontes, al-Hauz 3. West of Arjun	7302 3037; 504 m 7345 2783; 506 m 7348 2696; 506 m, to 7355 2716; 508 m	Bluff section in fluvial conglomerate Low cliffs and platforms showing cemented fluvial deposits, down to river level (Figure 4) Bluff in fine-grained (?) alluvial sediments above Mudan conglomerate	Probably equivalent to the ~5 m terrace recognized downstream, Qf0 of previous workers
Arjun	10 m	4. Arjun	7458 2573; 512 m	Quarry revealing fluvial sediments above Pliocene marl (Figure 2).	Probably equivalent to the ~10 m terrace recognized downstream, Qf1 of previous workers
Tir M'ala	19 m	5. Tir M'ala 6. Tir M'ala 7. Between Arjun and Dab'a	8986 5396; 470 m 9023 5296; 471 m 7615 2645; 522 m	Road-side section in ~1.5 m of well-cemented gravel and sand Exposure of fluvial conglomerate overlying weathered boulders or pillows of basalt surrounded by marl Quarry section: ~1 m of pure white alluvial marl	Probably equivalent to the 20–25 m terrace recognized downstream, part of QfII of previous workers
Ard al-Shamal	33 m	8. Ard al-Shamal	7762 2598; 534 m	Calcreted gravel at surface by dirt road	Probably equivalent to the 35 m terrace recognized downstream, part of QfII of previous workers
Mas'ud	41 m 47 m	9. Mas'ud 10. Al Qusayr	7877 2570; 542 m 7918 2288; 551 m	Calcreted gravel at surface by dirt road Calcreted gravel at surface by dirt road	
Al Qusayr		11. West of Bwayda al-Sharqiyya 12. West of Bwayda al-Sharqiyya	8337 3201; 540 m 8336 3225; 539 m	Quarry section in alluvial marl with decalcification features filled with flint gravel ~1 m deep post hole showing >0.6 m of conglomerate below 0.4 m of soil	
al-Salhiyya	59 m	13. al-Salhiyya	8209 2876; 552 m	Calcreted gravel at surface beside road	Probably equivalent to the Palaeolithic terrace at Latamneh (Figure 1), QfIII of previous workers
Bwayda al-Sharqiyya	75 m	14. Bwayda al-Sharqiyya 15. South of Homs 16. Rastan, motorway cutting	8482 3052; 567 m 9017 3987 to 9014 3976; 544 m 9349 6703; 417 m	Calcreted gravel at surface in bed of dirt road Channel-fill of calcreted fluvially bedded gravel and sand Superimposed channel fills, each ~12 m wide and ~3–4 m thick, the lower calcreted gravel with basalt boulders, the upper finer grained. Homs basalt at the base. The river is locally at ~327 m, ~90 m lower	All or part may be equivalent to the Khattab terrace, QfIV, of previous workers (see Figure 5). At Rastan, the river profile has a major nick point <sup>57</sup> , having recently incised through the base of the Homs basalt. This suggests a local ~15 m excess of incision over uplift, placing the terrace at ~+75 m relative to an equilibrium river profile
Dmayna	85 m	17. Dmayna 18. NW of Dahayraj 19. NW of Dahayraj	8512 2897; 580 m 8286 2394; 585 m 8301 2385; 587 m	Shallow bluff section Calcreted gravel beside road Calcreted gravel beside road	The two roadside exposures may possibly indicate two closely-spaced terrace levels (Figure 5)
Um al-Sakhr	97 m	20. Um al-Sakhr	8673 3142; 584 m	Section in >1 m of white alluvial marl, overlain by calcreted gravel and marly gravel, partly unconsolidated, which passes upwards into stone-free marl, its upper part (~1 m) decalcified	
Dahayraj West	109 m	21. Dahayraj West	8537 2249; 613 m	Calcreted gravel at surface by dirt road	
Dahayraj East	129 m	22. Dahayraj East	8846 2614; 625 m	Thick calcreted gravel in undulating road bed	
Higher terrace(s)	>~135 m	23. Between Dahayraj and the Damascus motorway	9008 2407; 653 m	Loose blocks, suggesting that at least one higher-level terrace is locally present	

To obtain accurate positioning, co-ordinates of sites were measured in the field using a portable GPS receiver, and are expressed as 8-digit grid references using the Universal Transverse Mercator (UTM) system. Height information has been taken from 1 : 50,000 maps, which have 5 m contour intervals, and interpolated to the nearest metre. All co-ordinates are in UTM quadrangle BU.



**Figure 3.** Summary map illustrating the Universal Transverse Mercator co-ordinates (within quadrangle BU) of exposures of Orontes fluvial deposits, our choice of terrace stratotype localities, and assignment of other exposures to individual terraces. Small symbols indicate other localities inspected in the field.

level of mapped conglomerates reveals their resolution into terraces, as is shown by plotting longitudinal and transverse profiles through the field area (Figures 5 and 6).

Calcreted gravels have been identified in exposure for all of the terraces indicated in Figures 5 and 6, but most are land-surface exposures only. Deep exposures have been observed at just a few localities, documented, along with essential details of type localities, in Table 1. This information should be regarded as preliminary; it is likely that further work will reveal additional, older terraces as well as supplementary evidence for the nature of those terraces recognized here.

Sections in the cemented Orontes deposits have invariably shown their upper surfaces to be decalcified, with prominent 'pipe' structures commonly reaching depths of a metre or more (Figure 2). The fabric of the conglomerates forming the higher (and therefore older)

terraces has been considerably modified by decalcification and recementation. Clasts (presumably calcareous ones) have been weathered out to leave cavities, which sometimes have been partly infilled with precipitated calcium carbonate. This means that the fluvial bedding structures are best preserved in the younger conglomerates, such as those forming the Arjun and al-Hauz terraces (Figures 2 and 4).

### Age estimation and modelling of fluvial incision in response to surface uplift

Mapping of *in situ* fluvial conglomerates within the survey area has revealed a staircase of at least twelve separate terraces (Figure 5; Table 1). No dating evidence has been obtained from the Homs area, but the terraces there can be compared, in terms of height above river level, with those in the Middle Orontes, where limited biostratigraphical evidence is available. As Figure 5 reveals, there is good agreement between the heights of the Middle Orontes terraces and those newly mapped in the Upper Orontes, although the former are fewer in number.

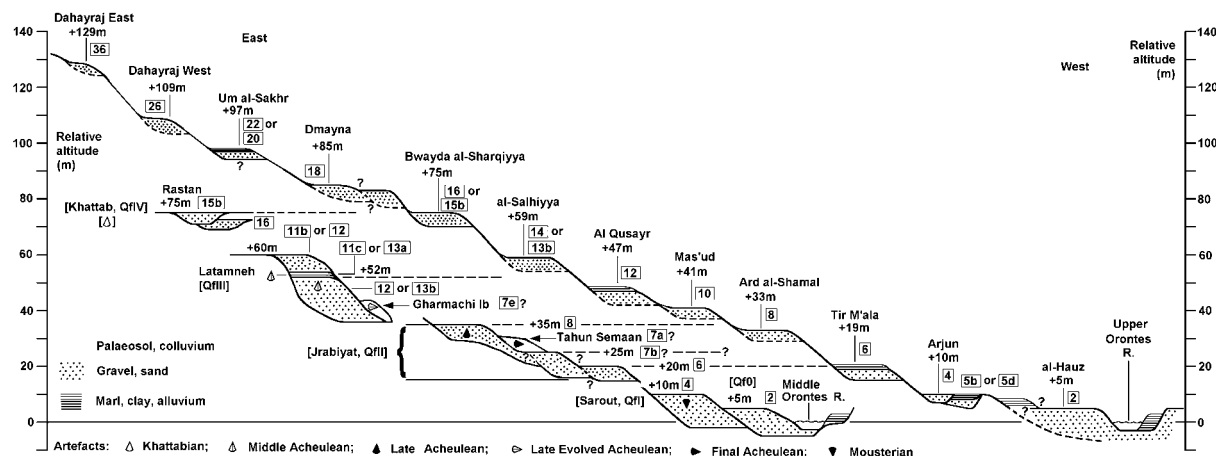
The key pinning point for biostratigraphical dating is a locality in the 60 m terrace at Latamneh (Figure 5), 150 km downstream from Homs (Figure 1, inset), where a mammalian assemblage has been recorded that includes *Mammuthus trogontherii*, *Stephanorhinus hemitoechus*, *Megaloceros verticornis* and *Equus cf. altidens*<sup>13,14</sup>. This assemblage combines mammoth and giant deer species that are unknown in Europe after the Elsterian with a rhinoceros that first appears in Europe immediately after that glacial, in the Holsteinian. The likely correlation with the oceanic oxygen isotope sequence is therefore probably with stage 13 (latest Cromerian Complex) or stage 11 (Holsteinian). The first implies an age of ~0.5 Ma, the second ~0.4 Ma.

The close agreement in terrace heights between the Upper and Middle Orontes (Figure 5) suggests that the terraces in the two reaches can be correlated. Upon this basis the more complete sequence in the Upper Orontes has been used to model surface uplift using a technique applied previously to terraces of the Rhine<sup>20</sup> and Thames<sup>21</sup>.

Previous workers<sup>3,5</sup> have attributed the incision of the Middle Orontes gorge and, by implication, the formation of terraces in that reach, to localized subsidence of the Ghab Basin, which has been widely interpreted as an actively-developing pull-apart basin on the Dead Sea Fault Zone<sup>22</sup>. The recognition here that the Upper Orontes has a comparable incision history means that localized subsidence is no longer a satisfactory explanation and that the Orontes terraces are likely to have formed in response to regional surface uplift. Similar sequences of sub-parallel terraces are widely observed in other regions and have been attributed to Quaternary uplift of land surfaces<sup>21,23-25</sup>. In temperate regions such as north-western Europe, river



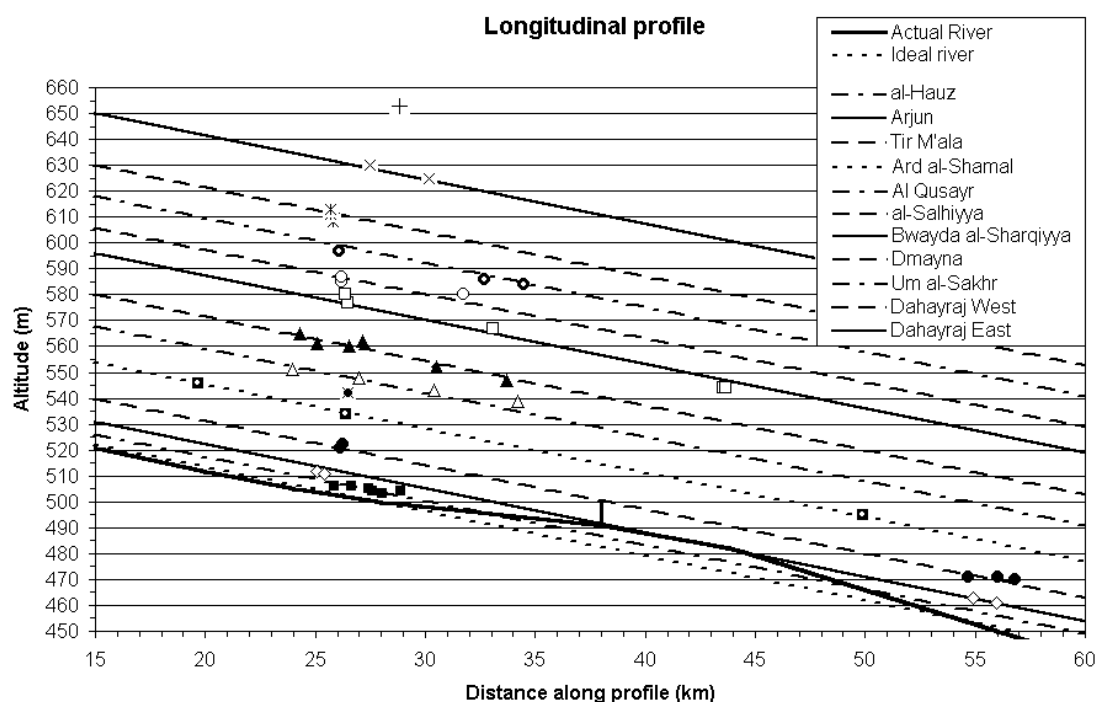
**Figure 4.** The conglomerate forming the lowest Orontes terrace, the al-Hauz terrace, exposed in the right bank of the Orontes opposite al-Hauz village (Table 1, Locality 2). Note that the cemented gravel extends continuously from ~5 m above river level to below the river level.



**Figure 5.** Idealized transverse section through the Orontes terraces in the Homs area. Bases of terraces and other field relations are shown dashed if not directly observed. A? symbol indicates that the interpretation is tentative. Terrace and archaeological evidence from the Middle Orontes<sup>3,9,58</sup> is shown, for comparison, to the left of the main staircase.

terraces have typically formed in uplifting areas in synchrony with climatic fluctuation, with the main incision phases coinciding with glacial to interglacial transitions<sup>26,27</sup>. At such times rivers would have experienced high magnitude seasonal flow, swollen with meltwater, while a reduced vegetation cover persisted, pending the inward migration of thermophilous flora. It seems likely that climatic triggering of terrace formation has also

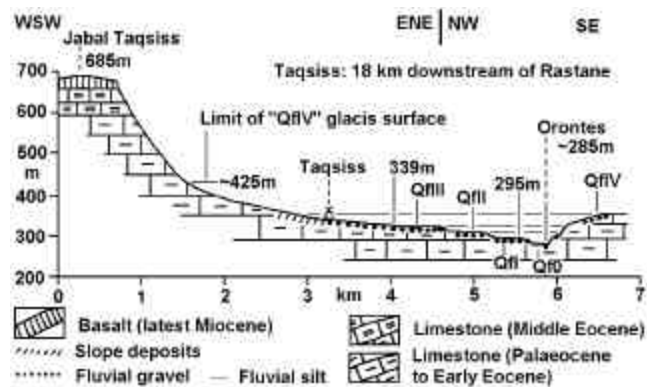
operated in Syria, but it remains to be demonstrated whether the mechanisms and timing are the same as further north. One line of evidence suggests that they are similar stems from observations on the Syrian coastline near Latakia (Figure 1). Here, marine terraces alternate with the fluvial terraces of the Nahr el-Kebir river (Figure 1)<sup>7,28</sup>, indicating that the river terraces did not form during interglacial high-stands<sup>12</sup>.



**Figure 6.** Longitudinal profile showing observations of Quaternary fluvial sediment and the terraces interpreted through them. The profile is projected along the line from S20°W to N20°E, with distances measured from zero at [BU 7200 0000]. The modern Orontes has a humped profile in the vicinity of Lake Qatina, probably as a consequence of the relative hardness of the Homs basalt, which it encounters at this point. Older terraces, at higher altitudes, will not come into contact with the basalt, so their profiles should not be humped. Thus the terrace sequence is projected onto a notional uniform river gradient, rather than assuming that the present variable gradient has existed throughout the Pleistocene.

A further control on the rate of long-term uplift is provided by the occurrence of Pliocene marine deposits at elevations of up to 300 m in a wide area of northern Syria (between the present coastline around Latakia and the Ghab basin) and in adjacent parts of southern Turkey<sup>29–33</sup>. Marine sediments inland of Latakia, almost 500 m thick, culminate in deposits biostratigraphically dated using foraminifera to the latest Pliocene<sup>31,34</sup>. This suggests uniform uplift during the last ~2.5 Ma at a time-averaged rate of at least ~0.12 mm a<sup>-1</sup>. Furthermore, the transition from continuous deposition of these sediments to a regime of uplift and erosion suggests that uplift at this substantial rate began some time in the Late Pliocene.

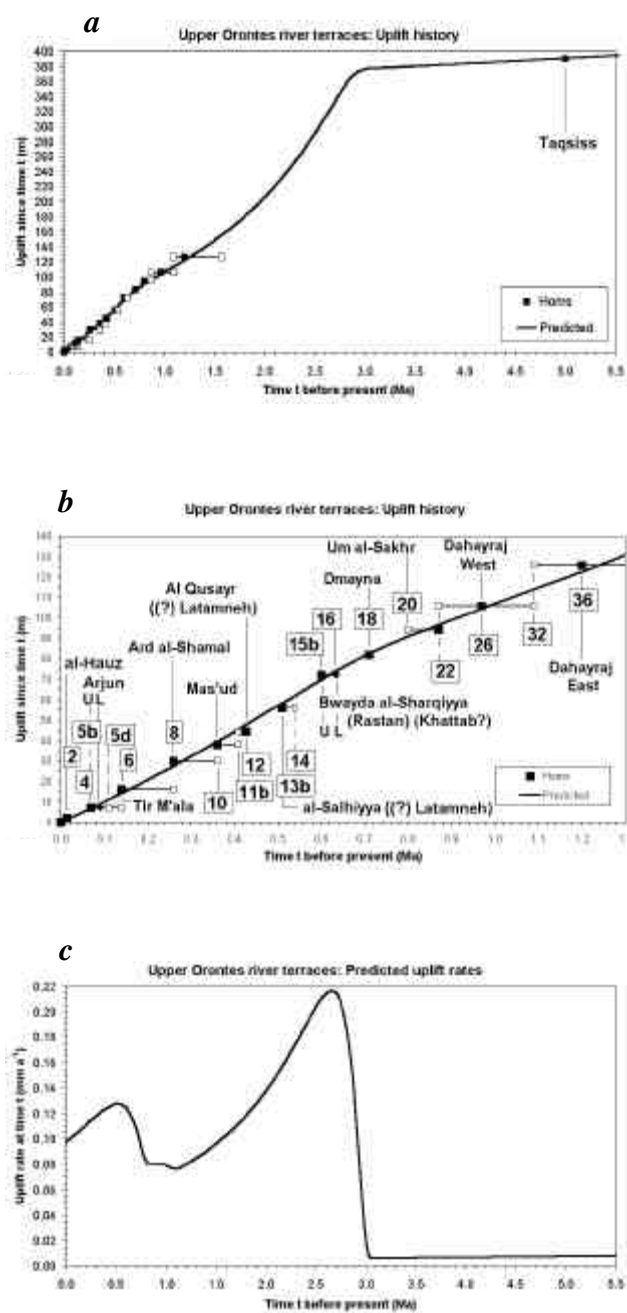
The altitude of the latest Miocene Homs Basalt above the Middle Orontes gorge at Taqsiiss, 18 km downstream of Rastan, where it is ~390 m above the river (Figure 7)<sup>3</sup>, measures the amount of incision since ~6 Ma and indicates much lower rates during the Early Pliocene than subsequently (Figure 8). This is consistent with similar first-order deductions about the landscape response in adjacent parts of southern Turkey<sup>33,35</sup>. Despite the proximity of the plate boundary zone, the Late Cenozoic uplift of south-eastern Turkey may be unrelated to plate motion, but result instead from the changing isostatic response to surface processes associated with environmental change<sup>35</sup>. It has been realized in recent years that many areas have comparable Late Cenozoic uplift histo-



**Figure 7.** Profile at Taqsiiss, indicating ~400 m of incision since the eruption of basalt, probably in the latest Miocene, inferred from part of Figure 9 of Besançon and Sanlaville<sup>3</sup>. Jabal Taqsiiss is located just north of the NE corner of Figure 1.

ries, irrespective of whether they are adjacent to a plate boundary zone or not<sup>24,36</sup>. The typical uplift pattern is one of acceleration at around 3 Ma, followed by a decrease during the Early Pleistocene and then a renewed increase at around the Early Pleistocene – Middle Pleistocene boundary, with the resulting high uplift rates continuing to the present-day. The modelling depicted in Figure 8, which assumes that this uplift pattern applies to the Upper Orontes, suggests oxygen isotope stage correlations for particular terraces, showing alternative ver-





**Figure 8.** Uplift histories. Calculations follow the method of Westaway<sup>20,21</sup>, and are based on the following parameter values:  $z_b$  (depth of the base of the brittle upper crust and top of the plastic lower crust) 17 km;  $z_c$  (depth where lower-crustal flow is concentrated) 27 km;  $\gamma$  (geothermal gradient in the lower crust) 20°C km<sup>-1</sup>; and  $k$  (thermal diffusivity of the lower crust)  $1.2 \times 10^{-6}$  m<sup>2</sup> s<sup>-1</sup>. Five phases of forcing of lower-crustal flow are considered, each characterized by a start time  $t_0$  and a parameter  $\Delta T_e$  that quantifies its magnitude, with:  $t_{0,1}$  18 Ma,  $\Delta T_{e,1}$  -16°C;  $t_{0,2}$  3.1 Ma,  $\Delta T_{e,2}$  -11.8°C;  $t_{0,3}$  2.5 Ma,  $\Delta T_{e,3}$  0°C;  $t_{0,4}$  1.2 Ma,  $\Delta T_{e,4}$  -0.8°C; and  $t_{0,5}$  0.9 Ma,  $\Delta T_{e,5}$  -3.4°C, the reasons for these timings being explained in detail elsewhere<sup>21</sup>. Uplift has been calculated from the relative altitudes of each terrace shown in Figure 6, minus a 3 m base-level correction. It has also been assumed that aggradation of each terrace finished at each glacial to interglacial transition, so terrace ages are matched to glacial maxima. (a), Predicted uplift history and supporting data for the Pliocene and Quaternary; (b), Enlargement of (a) showing the late Early Pleistocene onwards; (c) Predicted variation in uplift rates for the same time-scale as (a). See text for discussion.

sions constrained by the two most likely ages for the Latamneh deposits.

Two types of isostatic response that might account for uplift patterns of this sort have been suggested, both requiring the assumption that the lower continental crust is weak and readily deforms by flow. The first involves response to repeated cycles of surface loading and unloading by ice-sheets and sea-level fluctuations, whereas the second is driven by increasing rates of erosion caused by climate change<sup>20,21,25</sup>. The initial increase in uplift rates at ~3 Ma has been attributed to climate change and resultant increased erosion of weathered regolith<sup>21</sup>, whereas the second increase in uplift rates was probably brought about by the transition to 100 ka climatic cycles at the beginning of the Middle Pleistocene<sup>20,21</sup>. These cycles would have increased the amplitude of global sea level and ice volume fluctuations as well as potentially enhancing erosion rates<sup>20,21</sup>.

### Record of human occupation of the Orontes valley

River terrace sequences can be important archives of evidence for Quaternary environmental change and human occupation<sup>26,27</sup>. Long-timescale terrace sequences are known from many regions worldwide<sup>27</sup>, with important artefact assemblages from such sequences recorded from Europe<sup>37,38</sup>, Asia<sup>39,40</sup> and Africa<sup>41,42</sup>. In the Middle East, research on fluvial sequences has been patchy, although combinations of significant terrace systems and important archaeological records are documented from the Euphrates<sup>43,44</sup>, the Nile<sup>42</sup> and the Orontes itself<sup>3,9</sup>.

In the case of the Orontes, the previous research downstream of Homs identified no more than six clear terrace levels<sup>3,9</sup> but revealed important concentrations of artefacts at several localities. This permitted the construction of a working cultural stratigraphy for the Orontes Valley. The highest artefact-bearing terrace has yielded a small non-handaxe assemblage given the industrial designation 'Khattabian'<sup>12</sup>. This industry has been argued to represent the earliest known evidence of human occupation in the region and estimated to date from between 700 and >1000 ka<sup>12,39,45</sup>. Gravels assigned to this Khattab or QfIV terrace are generally situated ~80 m above the Orontes<sup>3</sup>, which suggests equivalence with the Bwayda al-Sharqiyya terrace (Figure 5; Table 1) or possibly with the Dmayna terrace of the upper Orontes. The ages suggested here for these terraces (OIS 16 and 18, or ~640 and ~700 ka; Table 1) are around the young end of the range previously estimated in the archaeological literature.

Gravels forming terraces QfIII and QfII have yielded many handaxe assemblages, assigned on a variety of stratigraphical, morphological and technological grounds to different phases of the Acheulean: Middle, Late, Late Evolved and Final Acheulean<sup>12</sup>. A notable instance is at

Latamneh (see above), where human occupation occurred between the deposition of two gravel units (Figure 5)<sup>10,11,46,47</sup> and coincided with the mammal fauna already mentioned. The Middle and Late Acheulean have been separated in the Middle East largely on the basis of handaxe shape and technology, which are thought by many European workers to have behavioural and contextual significance rather than direct chronological meaning<sup>48,49</sup>. The Levantine Late Evolved Acheulean and Final Acheulean are characterized by the increasing occurrence of Levallois<sup>12</sup>. In Europe, the persistent presence of Levallois has in recent years been taken as the marker for the beginning of the Middle Palaeolithic<sup>50,51</sup>, dating from ~250–300 ka (OIS 9/8) (refs 52, 53). Published sites in the Orontes that have yielded artefacts assigned to the Late Evolved Acheulean and Final Acheulean are unfortunately not in direct fluvial contexts (see Figure 5). At the Gharmachi Ib site (Figure 1), Late Evolved Acheulean has been recovered from a palaeosol capping gravel of the QfIII terrace, ~35 m above the Orontes<sup>12</sup> (Figure 5). Artefact-based correlation of this industry with that at Berekhat Ram in the Jaulan region (SW of Damascus, Figure 1), dated by K/Ar to ~233 ka<sup>54,55</sup> (early OIS 7), does not contradict the assignment of the ~35 m level of the QfII terrace to OIS 8 (Figure 5). At Tahun Semaan, on the left bank of the Orontes opposite Latamneh (Figure 1), Final Acheulean has been recovered from a palaeosol/colluvial deposit capping gravel of the QfII terrace, ~25 m above the Orontes<sup>12</sup>. The Final Acheulean of the Levant has been placed in the age range ~210 to ~150 ka or late OIS 7 to early OIS 6 (ref. 12). This is consistent with the interpretation of what appears to be a complex QfII terrace illustrated in Figure 5.

A sparse and largely undiagnostic Levantine Mousterian industry was recovered from the QfI terrace. Assemblages assigned to this industry in the southern Levant occupy a broad time span, of ~166–40 ka<sup>56</sup>, the latter part of which is consistent with our assignment of the QfI terrace to OIS 4.

In summary, the published age interpretations of the archaeological assemblages from the Middle Orontes<sup>12</sup> are in agreement with the terrace modelling conducted in the Homs Survey Area, with the first appearance of Levallois technique within the late Middle Pleistocene being particularly significant (Figure 5). As yet, no artefacts have been recovered from the terrace conglomerates of the Homs survey area, but collections made from the land surface during 2000, 2001 and 2002 included apparent Lower and Middle Palaeolithic material. The range of rocks from which these had been made suggests that the flinty conglomerates were the source of raw material in antiquity. It is also possible that some or all of the artefacts from the land surface were once incorporated in the terrace deposits, but have been liberated into the soil by the decalcification process noted above. Future research

will be designed to detect any patterns of artefact occurrence in connection with particular terraces.

## Conclusions

Geological and geomorphological mapping in the Homs region of Syria has revealed a staircase of at least 12 terraces on the eastern flank of the upper Orontes River, a significant enhancement of the sequence previously recognized in the middle and lower reaches of this system. Around Homs, where the terrace sediments overlie Pliocene lacustrine marl, they have been cemented by calcium carbonate. The relative hardness of these conglomerates has promoted their preservation and may have caused the upper Orontes to migrate systematically westward, repeatedly moving away from its former course in order to incise the softer Pliocene marl, potentially forming one of the most complete river terrace staircases anywhere in the world. Physical modelling of the regional-scale surface uplift responsible for this incision, which totals ~400 m since the latest Miocene, has been undertaken. This, together with correlation of terraces with dated terraces in the Middle Orontes and constraints provided by the elevation of Pliocene marine deposits and latest Miocene basalt, has provided a tentative terrace chronology. The oldest upper Orontes terrace so far identified, now ~130 m above the river, is thus dated to ~1.2 Ma. Lower down the terrace staircase, it would appear that every Middle and Late Pleistocene OIS climatic cycle is represented (Figure 5).

1. Westaway, R., *J. Geophys. Res.*, 1994, **99**, 12071–12090.
2. Erol, O., *il ve Tarih*, 1963, **148**, 1–110 (in Turkish and German).
3. Besançon, J. and Sanlaville, P., *Br. Archaeol. Rep. Int. Ser.*, 1993, **587**, 13–39.
4. de Vaumas, E., *Bull. Soc. Géogr. d'Égypte*, 1957, **30**, 97–236.
5. Van Liere, W. J., *Berichten Rijksd. Ovdheidk. Bodemonderzoek*, 1961, **11**, 7–69.
6. Van Liere, W. J., *Ann. Arch. Arabes Syr.*, 1966, **16**, 7–30.
7. Besançon, J., Copeland, L., Hours, F. and Sanlaville, P., *Bull. Inst. Archaeol., London*, 1978, **15**, 149–170.
8. Besançon, J., Copeland, L., Hours, F. and Sanlaville, P., *C. R. Acad. Sci. Paris*, 1978, **287**, 857–860.
9. Dodonov, A. E., Deviatkin, E. V., Ranov, V. A., Khatib, K. and Nseir, H., *Br. Archaeol. Rep. Int. Ser.*, 1993, **587**, 189–194.
10. Clark, J. D., *Quaternaria*, 1967, **9**, 1–68.
11. Clark, J. D., *Quaternaria*, 1968, **10**, 1–76.
12. Copeland, L. and Hours, F., *Br. Archaeol. Rep. Int. Ser.*, 1993, **587**, 63–144.
13. Guérin, C. and Faure, M., *Paléorient*, 1988, **14/2**, 50–56.
14. Guérin, C., Eisenmann, V. and Faure, M., *Br. Archaeol. Rep. Int. Ser.*, 1993, **587**, 169–178.
15. Mein, P. and Besançon, J., *Br. Archaeol. Rep. Int. Ser.*, 1993, **587**, 179–182.
16. Mouty, M., Delaloye, M., Fontignie, D., Piskin, O. and Wagner, J.-J., *Schweiz. Mineral. Petrogr. Mitt.*, 1992, **72**, 91–105.
17. Butler, R. W. H. and Spencer, S., *Geol. Soc. London Spl. Publ.*, 1999, **162**, 143–156.

18. Dubertret, L. and Vautrin, H., *C. R. Hebd. Seances Acad. Sci. Paris*, 1938, **206**, 69–71.
19. Kozlov, V., Artemov, A. and Kalis, A., *Geological Map of the Trablus (1-36-XVIII) and Homs (1-37-XIII) Quadrangles, 1:200,000 Scale, and Accompanying Explanatory Guide*, Vsesoj, Exportno-Import Objed. Technoexport, Moscow, and Ministry of Industry, Syrian Arab Republic, Damascus, 1963.
20. Westaway, R., in *River Basin Sediment Systems: Archives of Environmental Change* (eds Maddy, D., Macklin, M. and Woodward, J.), Balkema, Rotterdam, 2001, pp. 87–167.
21. Westaway, R., Maddy, D. and Bridgland, D., *Quat. Sci. Rev.*, 2002, **21**, 559–603.
22. Brew, G., Lupa, J., Barazangi, M., Sawaf, T., Al-Imam, A. and Zaza, T., *J. Geol. Soc. London*, 2001, **158**, 665–674.
23. Maddy, D., *J. Quat. Sci.*, 1997, **12**, 539–545.
24. Westaway, R., *Netherlands J. Geosci.*, 2002, **81**, 305–328.
25. Westaway, R., *Netherlands J. Geosci.*, 2002, **81**, 283–303.
26. Bridgland, D. R., *Quat. Sci. Rev.*, 2000, **19**, 1293–1303.
27. Bridgland, D. R. and Maddy, D., *Netherlands J. Geosci.*, 2002, **81**, 265–282.
28. Besançon, J. and Sanlaville, P., *Bull. Assoc. Française l'Étude Quat.*, 1984, **21**, 186–191.
29. Tolun, N. and Erentöz, C., *Hatay sheet of the Geological Map of Turkey, 1:500,000 scale*, General Directorate of Mineral Research and Exploration, Ankara, 1962.
30. Shatsky, V. N., Kazmin, V. G. and Kulakov, V. V., *Geological Map of the Al-Lathequieh (I-36-XXIV) and Hama (I-37-XIX) Quadrangles, 1:200,000 scale, and Accompanying explanatory guide*, Vsesoj, Exportno-Import Objed. Technoexport, Moscow, and Ministry of Industry, Syrian Arab Republic, Damascus, 1963.
31. Ponikarov, V. P. et al., *The Geology of Syria. Explanatory Notes on the Geological Map of Syria, Scale 1:500,000. Part 1: Stratigraphy, Igneous Rocks and Tectonics*, Vsesoj, Exportno-Import Objed. Technoexport, Moscow, and Ministry of Industry, Syrian Arab Republic, Damascus, 1967.
32. Sanlaville, P., Dalongeville, R., Bernier, P. and Evin, J., *J. Coastal Res.*, 1997, **13**, 385–396.
33. Yurtmen, S., Guillou, H., Westaway, R., Rowbotham, G. and Tatar, O., *Tectonophysics*, 2002, **344**, 207–246.
34. Ponikarov, V. P. et al., *The Geological Map of Syria, Scale 1:1,000,000. Explanatory Notes*, Vsesoj, Exportno-Import Objed. Technoexport, Moscow, and Ministry of Industry, Syrian Arab Republic, Damascus, 1966.
35. Arger, J., Mitchell, J. and Westaway, R., *Geol. Soc. London Spl. Publ.*, 2000, **173**, 459–487.
36. Van den Berg, M. W., *Geologie en Mijnbouw*, 1994, **73**, 143–156.
37. Roebroeks, W. and Van Kolfschoten, T. (eds), *Proceedings of the European Science Foundation Workshop, Tautavel*, Institute of Prehistory, Leiden, 1995, vol. 27, p. 332.
38. Wymer, J., *The Lower Palaeolithic Occupation of Britain*, Wessex Archaeology and English Heritage, Salisbury, UK, 1999.
39. Bar-Yosef, O., in *Early Human Behaviour in Global Context: The Rise and Diversity of the Lower Palaeolithic Record* (eds Petraglia, M. D. and Korisettar, R.), Routledge, London, 1998, pp. 221–279.
40. Korisettar, R. and Rajaguru, S., in *Early Human Behaviour in Global Context: The Rise and Diversity of the Lower Palaeolithic Record* (eds Petraglia, M. and Korisettar, R.), Routledge, London, 1998, pp. 304–342.
41. Helgren, D. M., *J. Archaeol. Sci.*, 1978, **5**, 39–60.
42. Said, R., *The River Nile, Geology, Hydrology and Utilization*, Pergamon Press, Oxford, 1993, p. 320.
43. Tyracek, J., *Sbornik. Geol. Ved, Antropozoikum*, 1987, **18**, 185–202.
44. Minzoni-Deroche, A. and Sanlaville, P., *Paléorient*, 1988, **14**, 87–98.
45. Copeland, L. and Sanlaville, P., *Br. Archaeol. Rep. Int. Ser.*, 1993, **587**, 201–204.
46. Hooijer, D. A., *Ann. Arch. Arabes. Syr.*, 1962, **11**, 117–132.
47. Heinzelin, J., *Ann. Arch. Arabes. Syr.*, 1966, **16**, 115–120.
48. Wymer, J. J., in *Central East Anglia and the Fen Basin, Field Guide* (eds Lewis, S. G., Whiteman, C. A. and Bridgland, D. R.), Quaternary Research Association, London, 1991, pp. 45–48.
49. White, M. J., *Proc. Prehistoric Soc.*, 1998, **64**, 15–45.
50. Ronen, A. (ed.), *Br. Archaeol. Rep. Int. Ser.*, 1982, **151**.
51. Roebroeks, W. and Gamble, C. (eds), *The Middle Palaeolithic Occupation of Europe*, Institute of Prehistory, Leiden.
52. Bridgland, D. R., *Quaternary of the Thames*, Chapman & Hall, London, 1994, p. 441.
53. White, M. J. and Ashton, N. M., *Curr. Anthropol.*, in press.
54. Feraud, G., York, D., Hall, C. and Schwarcz, H. P., *Nature*, 1983, **304**, 263–265.
55. Goran, N., *Paléorient*, 1985, **11/1**, 7–28.
56. Bar-Yosef, O., in *The Evolution and Dispersal of Modern Humans in Asia* (eds Akazawa, T., Kenichi, A. and Kimura, T.), Hokusensha, Tokyo, 1992, pp. 189–216.
57. Weulersse, J., *L'Oronte étude de fleuve*, Arrault, Tours, France, 1940.
58. Muhesen, S., *Br. Archaeol. Rep. Int. Ser.*, 1993, **587**, 145–166.

ACKNOWLEDGEMENTS. This research forms part of the project 'Settlement and Landscape Development in the Homs Region, Syria', a joint project of the University of Durham and the Directorate General of Antiquities and Museums (DGAM), Syria. The fieldwork is sponsored and funded by the Council for British Research in the Levant. We gratefully acknowledge the contributions made by Abd el-Razzaq Moaz, Director General of Antiquities and Museums, and Michel Maqdissi, Director of Excavations. Support of fieldwork and administration in Homs was ably provided by Farid Jabbur and Maryam Bshesh, from the Homs Office of the DGAM. This publication is a contribution to International Geological Correlation Programme 449: 'Global Correlation of Late Cenozoic fluvial sequences'.